Rust Diseases of Apples and Their Control in the Hudson Valley

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Cover illustration

Apple rust gall on cedar twig ready to discharge spores following a spring rain. (Color by courtesy of E. I. du Pont de Nemours Company.)

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D. H. PALMITER

Abstract

The life histories of the three common apple rust fungi, *Gymnosporangium juniperi-virginianae* Schw., *G. globosum* Farl., and *G. clavipes* Cke. and Pk., are briefly reviewed and disease symptoms caused by these fungi on the two alternate hosts, apple and red cedar, *Juniperus virginiana* L., described.

Data on the control of these rust diseases have been obtained from field experiments in which various fungicides have been compared in spray and dust applications over a period of 10 years.

The carbamate group of fungicides, especially those of the ferbam type (ferric dimethyldithiocarbamate), has been found to be highly specific in its toxicity towards the rust fungi. Amounts as low as ½ pound in 100 gallons of water proved to be more effective than 5 pounds of dry wettable sulfur.

A combination of ferbam and sulfur was shown to be satisfactory for the control of both rust and apple scab, *Venturia inaequalis* (Cke.) Wint., when used in the recommended spray schedule.

In orchards where both rust and scab were problems, the addition of ferbam to any of the organic fungicides used for scab usually resulted in improved rust control.

A ferbam-sulfur dust program resulted in good control of apple rust diseases when a protective schedule was followed.

Introduction

Until recent years apple rust diseases were a limiting factor in the production of certain susceptible varieties in eastern New York. In 1929, Thomas and Mills[1] reported three species of rust fungi causing destructive diseases of apples in the Hudson Valley. They indicated that the application of fungicides offered some promise in control of fruit infection but concluded that eradication of red cedars seemed to be the best method of control for all three diseases.

In 1937, Hamilton[2] reported on two years' extensive field tests with

[1]Thomas, H. E., and Mills, W. D. Three rust diseases of apple. *Cornell Univ. Agr. Exp. Sta. Mem. No. 123: 1–21. 1929.*

[2]Hamilton, J. M. Recent investigations on the control of cedar-apple rust in the Hudson Valley. *New York State Ag. Exp. Sta. Bul. No. 678: 1–34. 1937.*

copper and sulfur fungicides for the control of cedar apple rust. He concluded that it was possible to obtain commercial control by means of frequent thorough applications of wettable sulfurs of fine particle size. Liquid lime-sulfur and bordeaux mixture gave better control but caused excessive injury.

The organic fungicide ferbam (ferric dimethyldithiocarbamate) has been tested extensively since 1940 in the Hudson Valley for the control of the apple rusts.[3] Other recently developed fungicides have been compared with ferbam to ascertain their effectiveness in controlling apple rusts. The results of these tests are presented in this bulletin.

Life Histories and Symptoms on Apple and Cedar

The most common of the three apple rusts in the Hudson Valley is cedar-apple rust. It may cause orange lesions on both leaves and fruit of susceptible varieties. The quince rust occurs on apple fruit as well as quince fruit but seldom develops on leaves. Hawthorn rust, on the other hand, produces lesions on apple and hawthorn leaves but not on the fruit. All three of these fungi spend part of their life cycle on red cedar or juniper trees, *Juniperous virginiana* L.

Cedar-apple Rust

The fungus *Gymnosporangium juniperi-virginianae* Schw., the cause of cedar-apple rust, spends almost two years of its life cycle on red cedar trees (Fig. 1).[4] Cedar leaves may be infected in July and August by aeciospores blown from diseased apple trees. Some spores may remain dormant on the cedar and start infection as spring growth starts.[5] Small brown galls appear on cedars during the summer but do not mature until the following spring (Fig. 2). After a few warm spring rains, these galls increase in size and extrude gelatinous tendrils from all sides. (See cover page illustration.) These tendrils or "horns" consist of masses of two-celled teliospores. These spores germinate in the tendrils by producing four small sporidia from each of the two cells.

All of the teliospores do not germinate at the same time. With each rain the horns push out farther and expose more spores. After the small sporidia are produced, a decrease in humidity causes them to be forcibly

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[3]Palmiter, D. H. A new fungicide. *Proc. New York State Hort. Soc., 87: 207–209. 1942.*

[4]Figures 1, 2, 3, 4, and 5 have been reproduced from Bulletin No. 678 of this Station, now out of print.

[5]Miller, Paul R. The relation of aeciospore germinability and dissemination to the time of infection and control of *Gymnosporangium juniperi-virginianae* on red cedar. *Phytopath., 29: 812–817. 1939.*

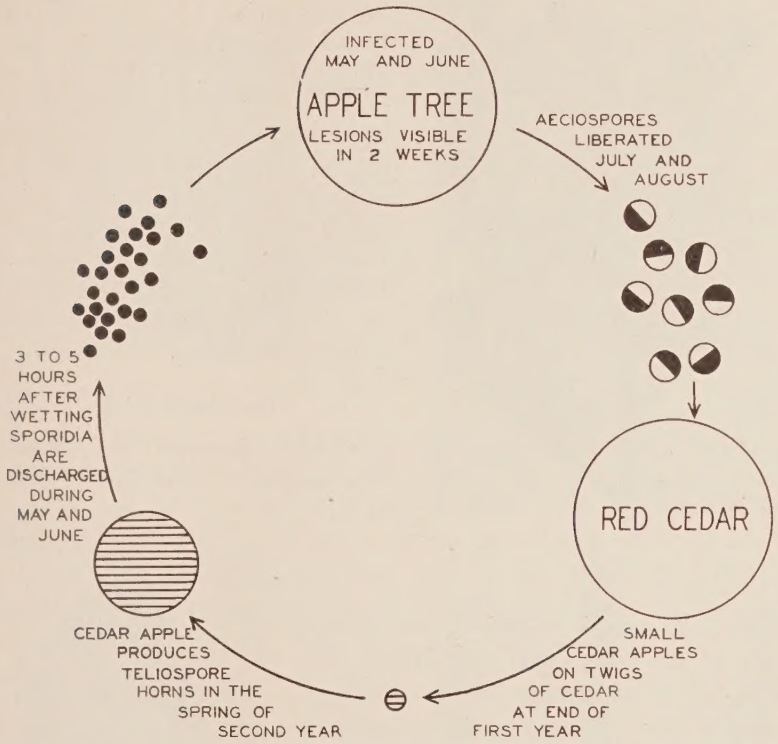

FIG. 1. — *Diagram of life cycle of apple rust fungus. Note that the spores produced on the apple (aeciospores) do not re-infect the apple. Only spores produced on the cedar galls (basidiospores) can infect the apple.*

discharged into the air. They are carried about by air currents and may eventually settle on an apple leaf or fruit. If a film of moisture is present and the temperature is between 56° and 61° F, the sporidia quickly germinate and penetrate the host tissue within 4 hours. At higher or lower temperatures germination and penetration require more time.

After 1 to 3 weeks, depending on the temperature and the susceptibility of the variety, the rust spots become visible on the upper surface of the apple leaves. As these yellow spots, or pycnia, increase in size, a sticky exudate containing pycniospores becomes evident (Fig. 3). Insects are attracted to this exudate and, as vectors, carry the pycniospores from one pycnium to another. The sexual pycniospores occur as plus and minus strains which cross fertilize. After fertilization the fungus grows through the apple leaves to the lower surface, resulting in the develop-

FIG. 2.—*"Cedar apple" or gall of apple rust fungus on red cedar.*

ment of aecia.[6] The production of spores (aeciospores) in these aecia during July and August completes the life cycle of the fungus. Aecia may also be produced on the fruit (Fig. 4). Now that better control methods are available, few spores are produced on commercial apple trees. Infection of cedar trees is caused largely by spores produced on wild seedling apple trees growing near the cedars.

Hawthorn Rust

The life history of the hawthorn rust fungus, *Gymnosporangium globosum* Farl., is essentially the same as that of the cedar-apple rust fungus. The galls are not as common on the cedar trees, but the same galls may persist and produce spores for several years. This fungus may infect leaves of McIntosh and Cortland, which are not susceptible to cedar-apple rust, but some varieties are susceptible to both rusts. Spores from infected hawthorn trees serve to re-infect cedars.

FIG. 3.—*Rust spots on the upper surface of apple leaves are bright yellow.*

Quince Rust

The quince rust fungus, *Gymnosporangium clavipes* Cke. and Pk., infects twigs, branches, and trunks of the red cedar but not the leaves. It produces elongated, swollen, deep red cankers from which

[6]Liu, J. C. Investigations on the sexual behavior of the apple rust fungus. Unpublished doctorial dissertation filed at the University of Wisconsin Library, Madison, Wis. 1933.

FIG. 4. — *Apple rust lesions on Rome Beauty fruit.*

masses of yellow-orange teliospores exude during the spring rains (Fig. 5). These cankers remain active year after year until the twig or the branch dies. Spore forms are similar to those of the cedar-apple rust fungus.

FIG. 5. — *Cankers of the quince rust fungus on cedar twigs as they appear after spring rains.*

Infections on apple are generally limited to the fruit and usually no aecia are produced on cultivated apples, but aecia are produced abundantly on quince and hawthorn fruit (Fig. 6). The aeciospores produced on infected quince or hawthorn fruit are then able to re-infect cedar trees. Infected apple fruits often drop in June and those that mature are misshapen with sunken dark green lesions usually found near the blossom end. Some varieties such as Cortland tend to crack from quince rust infections, and the hardened tissue under the sunken area extends to the apple core (Fig. 7).

Experiments with Spray Materials

Methods

Fungicide trials were carried out in commercial orchards selected for their previous record of severe infection. Because of unequal distribution of inoculum, single-tree plots replicated several times were used

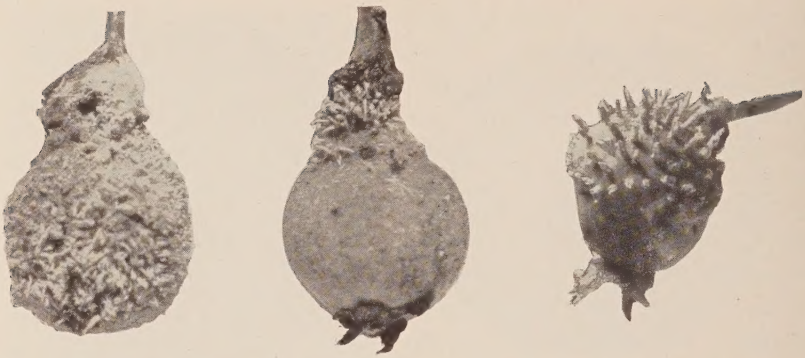

FIG. 6. — *Quince rust fungus producing spores on quince (left and center) and on hawthorn (right).*

whenever possible. It was found that a more even distribution of inoculum was obtained in a block of apple trees located approximately ¼ mile from cedar trees and such locations were selected for most of the trials.

The spray materials were mixed in the tank according to standard recommendations. All treatments were made with a standard high pressure sprayer operated at 400 to 600 pounds pressure. Applications were made from the ground with a spray gun.

In certain experiments the test materials were used throughout the season to check their effectiveness for scab control, but in other experiments the treatments were started with the pink application and ended with the second or third spray following bloom as these were the only applications affecting rust control.

FIG. 7. — *Quince rust lesions on apple. Note sunken areas and deep cracks.*

Timing of applications was determined by rate of tree development and the indication of rain periods. Protection of new growth immediately prior to rain periods was attempted.

Arsenate of lead at 3 pounds per 100 gallons of spray was used in combination with the fungicides for insect control in all post-bloom applications. Spray lime was not used except as indicated.

In order to include the protection afforded by the test fungicides between spray applications, the data were taken at the end of the rust season instead of for individual infection periods.

Data on cedar-apple and hawthorn rust infection on the leaves were obtained by examination of 25 to 30 terminals per tree. No distinction between the two rusts was attempted. Terminals of uniform growth were selected at shoulder height around each tree. From two to six trees were examined for each treatment. The number of rust lesions on each leaf was determined and the results presented as the average number of rust lesions per leaf for each leaf position on the terminals. The data presented in graphic form show which leaves were exposed to infection and the point of failure of the weak treatments.

Counts of fruit infected with cedar-apple rust and quince rust were made at harvest when all the apples were examined.

Materials

Wettable sulfurs

Micronized sulfur, a 93.4 per cent sulfur product with 46.5 per cent by weight composed of particles less than 4 microns in diameter, was used as the standard reference fungicide in practically all experiments. It was produced by Corona Chemical Division, Pittsburgh Plate Glass Co., Moorestown, N. J.

Koppers flotation sulfur paste, containing 45 per cent sulfur, was tested in 1948. It was produced by the Koppers Company, Inc., Everett, Mass.

Phenyl mercury compounds

Puratized N5X, a liquid containing 10 per cent phenyl mercuric triethanol ammonium lactate, was tested in 1944. It was produced by Gallowhur Chemical Corp., New York, N. Y.

Puratized Agricultural Spray, a liquid containing 5 per cent phenyl mercuric triethanol ammonium lactate, was tested in 1948. It was produced by the Gallowhur Chemical Corp., New York, N. Y.

Tag Fungicide No. 331, a liquid containing 10 per cent phenyl mercuric acetate, was tested in 1948 and 1949. It was procured from the California Spray Chemical Corp., Elizabeth, N. J.

Puratized Apple Spray, a liquid containing 11.5 per cent phenyl mercuric monoethanol ammonium acetate, was tested in 1949. It was produced by the Gallowhur Chemical Corp., New York, N. Y.

Dithiocarbamates

Ferbam, Fermate, a wettable powder containing 76 per cent ferric dimethyldithiocarbamate, was tested from 1941 to 1949. It was produced by E. I. duPont de Nemours and Co., Inc., Wilmington, Del.

Nabam, Dithane D-14, a liquid containing 25 per cent disodium ethylene bisdithiocarbamate hexahydrate, was tested in 1945 and 1946. A dry form, He 175, was tested in 1944. Both forms were produced by Rohm and Haas Co., Philadelphia, Pa.

Zineb, Dithane Z-78 (1946 He 178), a wettable powder containing 65 per cent zinc ethylene bisdithiocarbamate, was tested in 1946. It was produced by Rohm and Haas Co., Philadelphia, Pa.

Naphthoquinone

Phygon-XL, a wettable powder containing 50 per cent 2,3–dichloro-1,4-naphthoquinone, was tested in 1948 and 1949. It was produced by Naugatuck Chemical Division, U. S. Rubber Co., Naugatuck, Conn.

Glyoxalidines

Crag Fruit Fungicide 341C, a liquid containing a 56 per cent mixture of glyoxalidines in isopropanol, was tested in 1948 and 1949. It was produced by Carbide & Carbon Chemical Co., New York, N. Y.

Organic sulfur

Cr-305, a 50 per cent wettable powder containing bis(2-hydroxy,5-chloro-phenyl) sulfide as the active ingredient, was tested in 1949. It was produced by Rohm and Haas Co., Philadelphia, Pa.

Phthalimide

Orthocide 406, a 50 per cent wettable powder containing N-trichloro-methyl-thiotetrahydrophthalimide, was tested in 1952. It was produced by California Spray Chemical Corp., Elizabeth, N. J.

The concentrations of dry materials are expressed in this bulletin as pounds per 100 gallons of spray and concentrations of liquids as pints per 100 gallons. Thus, 3 pounds of sulfur and ½ pound of Fermate in 100 gallons of water would be expressed as sulfur-Fermate 3–½–100. One half pint of Tag Fungicide No. 331 in 100 gallons of water would be expressed as Tag ½ pt.–100.

Results

1941 Season

A block of Rome Beauty trees on the Giles Randall farm at New Paltz was used because of its previous history of rust infection. Weather was dry during April and the trees reached the pink stage by April 28 with no infection. The pink spray was applied on that date, but no rain fell until the following week. The trees were in bloom May 5 and a special spray application was made. The application was followed by a 5-hour rain at 60° F. Cedar-apple galls were ready to discharge spores

following this rain, but quince rust cankers were not advanced sufficiently for spore discharge.

Two 12-hour wet periods, 55° to 60° F, occurred May 8 and 9. The petal-fall application was made May 16 and was followed by showers May 17 and 23. Rust lesions were evident on the fifth to eighth leaves by May 27 as a result of infection which occurred May 8 and 9. The first cover spray was applied May 28 and was followed by heavy rains June 1 to 2 and June 4 to 5. The second cover spray was applied June 12 and was followed by rain June 13 which exhausted the cedar-apple galls.

Very little fruit infection developed this season. Quince rust galls failed to discharge spores during the short bloom period.

Rust count on the foliage was made June 26. The results showed heaviest infection on the eleventh terminal leaf. Trees that received no fungicide averaged 7 lesions per leaf compared with an average of 3.5 lesions per leaf on trees sprayed with Micronized sulfur 5–100 and 0.1 lesion per leaf on those sprayed with Fermate ½–100 (Fig. 8).

Sulfur-sprayed trees, with the bloom application of May 5 omitted, averaged 5.5 lesions per leaf, while comparable trees sprayed with Fermate ½–100 and Fermate 1½–100 averaged 2.5 and 0.6 lesions per leaf, respectively.

1943 Season

Rome Beauty trees at the Moriello Brothers orchard in New Paltz were used in 1943 for a comparison of Micronized sulfur, Fermate, and combinations of the two materials in a cedar-apple and quince rust control test. Weather conditions were favorable for rust infection. Both cedar-apple rust and quince rust galls were ready to discharge spores May 7 when the apple trees were in the early pink stage. All trees were given an early pink application of wettable sulfur 6–100 May 10 by the grower. The three Fermate plots were resprayed the same day with Fermate ¼–100 because rain threatened. This application was followed by rain during six of the next eight days. The trees were in full bloom May 18 and the scheduled treatments were applied. This application was followed by a 12-hour wet period that day, a 15-hour wet period May 19, and an 18-hour wet period May 21. The petals had fallen by May 25 and the trees were sprayed again. Four long rain periods occurred between May 25 and June 9 when the first cover spray was applied. Two more rain periods, one of 14 hours June 11 and another of 13 hours June 17, ended the rust season for 1943.

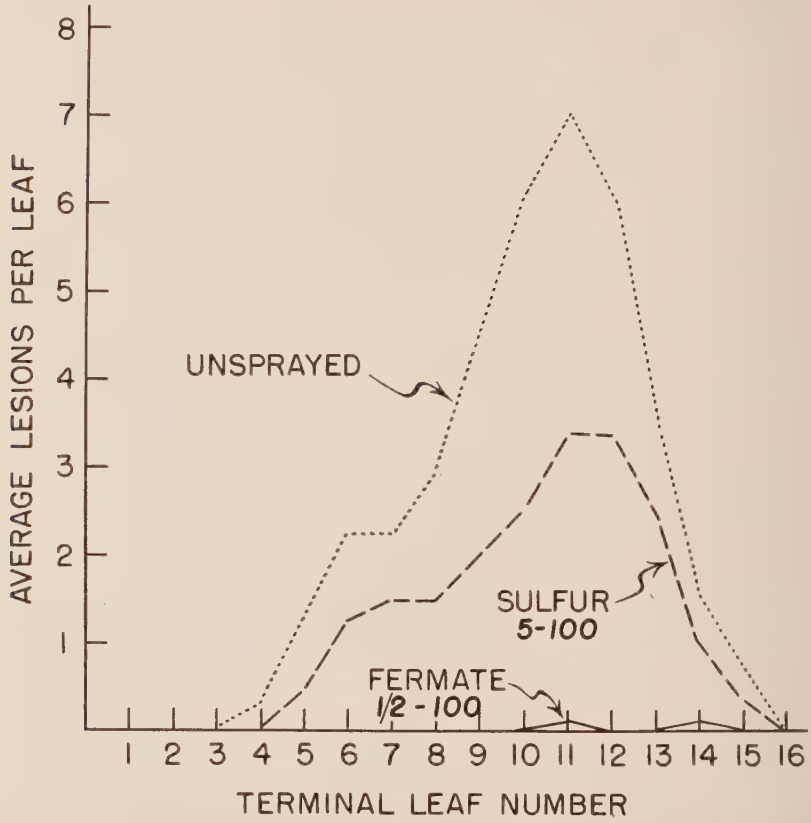

FIG. 8.—*Average number of rust lesions on terminal leaves of Rome Beauty trees in spray plots, 1941. Unsprayed trees averaged 7 rust lesions on the 11th terminal leaf. Micronized sulfur 5–100 resulted in 50 per cent control with an average of 3.5 lesions per leaf. Fermate ½–100 resulted in almost complete control.*

Apple rust lesions on the leaves were visible May 26. Apple and quince rust lesions were observed on the fruit May 30.

Leaf counts made during July indicated that the amount of leaf infection in all plots was relatively low considering the abundant rainfall. The low number of lesions per leaf was probably due to the frequent spray applications (7- to 8-day intervals). This is supported by the fact that sulfur 3–100 gave as good protection as sulfur 5–100. The fruit was not equally protected, probably because the sulfur residue was more readily washed from the fruit.

In plots where bloom sprays were omitted, sulfur 5–100 averaged 88 and 85 per cent control of apple and quince rust, respectively (Table

1). The combination of sulfur and Fermate 3–½–100 or 3–¼–100 increased the control of both rust diseases about 10 per cent above straight sulfur treatment.

The use of Fermate 1–100 in pink, bloom, and petal fall applications resulted in complete control of apple rust, quince rust, scab, and Brooks' fruit spot, *Mycosphaerella pomi* (Pass.) Lindau. The sulfur-Fermate mixture 3–½–100 was almost as effective (Table 1). The sulfur treatment gave fair rust control when the bloom application was used but was less effective than Fermate in controlling Brooks' fruit spot.

A block of Cortland trees located in the H. C. Frey orchard, Dutchess County, was also used for a quince rust control experiment.

A mixture of Micronized sulfur and Fermate 3–½–100 was used in comparison with Micronized sulfur 5–100 in the regular scab spray schedule for both quince rust and scab control. The spray applications involved in quince rust control were made at the pink (May 11), bloom (May 19), and petal fall (May 26) stages. Earlier and later sprays of the same fungicides were applied for scab control.

The sulfur program resulted in 93 per cent control of quince rust and 85 per cent control of fruit scab. The sulfur-Fermate mixture resulted in 100 per cent control of quince rust and 99 per cent control of scab. On unsprayed trees 20 per cent of the fruit was infected by quince rust and 100 per cent by scab.

Jonathan trees in the same orchard were also sprayed with the two fungicide programs. No fruit was available for rust counts, but leaf

TABLE 1. — *Effectiveness of Sulfur and Fermate for Control of Rusts and Other Diseases on Rome Beauty Apples, New Paltz, N. Y., 1943.*

TREATMENT*	PERCENTAGE CONTROL			
	Apple rust	Quince rust	Apple scab	Brooks' fruit spot
Without Bloom Spray				
Sulfur, 5–100	88	85	96	....
Sulfur, 3–100	87	86	94	....
Sulfur & Fermate, 3–¼–100	98	94	87	....
Sulfur & Fermate, 3–½–100	96	93	95	....
With Bloom Spray				
Sulfur, 5–100	96	95	96	87
Sulfur, 3–100	94	94	95	86
Fermate, 1–100	100	100	100	100
Sulfur & Fermate, 3–¼–100	98	98	98	....
Sulfur & Fermate, 3–½–100	100	100	99	....

*Rust sprays were applied at pink (May 10), bloom (May 18), petal fall (May 25), and first cover (June 9). Micronized sulfur used in the rust applications. Other sulfur sprays were applied for scab control before and after the above rust applications.

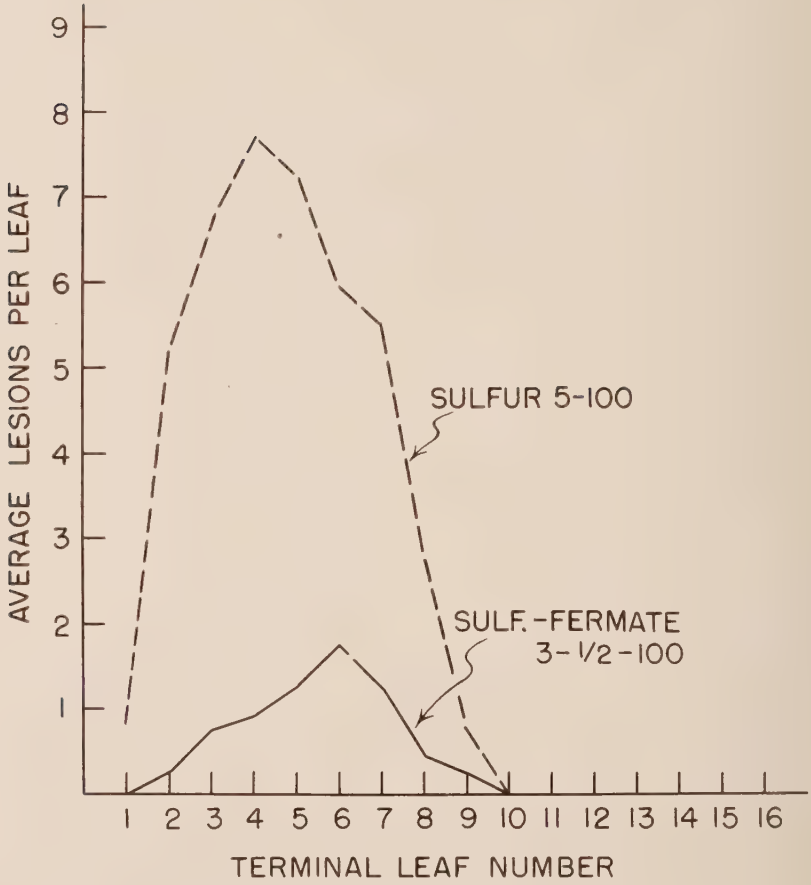

FIG. 9.—*Average number of rust lesions on terminal leaves of Jonathan trees in spray plots, 1943. Trees sprayed with Micronized sulfur averaged about 7.6 rust lesions per leaf on the 3rd to 5th terminal leaves. Sulfur-Fermate 3-½-100 reduced infection to less than 2 lesions per leaf.*

counts were made to determine the amount of cedar-apple rust infection. Trees sprayed with Micronized sulfur averaged eight rust lesions per leaf compared with less than two lesions per leaf for those treated with the sulfur and Fermate mixture (Fig. 9).

1944 Season

The 1944 season was relatively dry during May when rust infections usually occur. The total rainfall for the month was 1.61 inches, about one-half normal. One 12-hour wet period occurred May 7 when the

trees were in the early pink stage and few leaves were exposed. A rainfall of 0.12 inch occurred during bloom and kept the trees wet over night at 45° to 70° F. Lesions were evident May 27. Following petal fall, a 3-day wet period occurred May 22 to 24. Scattered showers totaled 0.58 inch of rain and cloudy calm weather prevented complete drying between showers. Further light rains May 26 to 27 may have resulted in some new leaf infections.

The experiment was located on the Hall Farm at High Falls in Ulster County in a block of Winter Banana apples. Many cedar trees were located in this area and severe rust infections had occurred in this orchard in 1943. The materials tested included Micronized sulfur 5–100, sulfur-Fermate 5–½–100, Fermate 1–100, Dithane He 175 1–100, and Puratized N5X at ½ pt.–100. These fungicides were applied in the pink, petal fall, and 10-day applications May 9, 20, and 27, respectively.

Very little fruit infection occurred. The amounts of rainfall during the rust infection periods were not sufficient to remove the spray residue, so only new unprotected leaf growth became infected. Considerable leaf infection (6 to 11 spots per leaf) occurred on the 6th to 9th terminal leaves of trees sprayed with sulfur and mercury fungicides (Fig. 10). In contrast, trees sprayed with Fermate 1–100 or sulfur and Fermate 5 -½ -100 averaged less than one lesion per leaf. Dithane He 175 1–100 did not give quite as good protection as Fermate.

1945 Season

Rust control experiments were conducted in the same Rome Beauty orchard at New Paltz as in 1943. The 1945 season opened two weeks early. Apple trees were in the delayed dormant stage April 1, and apple rust galls on cedars were ready to discharge spores at this time. Apple trees bloomed April 10 to 30. Frost April 22 greatly reduced the set of fruit. Two wet periods occurred during bloom. On April 17 the trees were wet 10 hours at 48° F and April 24 to 26 they were wet 28 hours at 52° F. The petal fall spray was applied April 30 and was followed by rain May 1, 3, and 4. The heaviest infection of the season occurred on the 11th terminal leaf as a result of rain on May 8.

The test materials included Micronized sulfur 5–100, sulfur-Fermate 3–¼–100 and 3–½–100, Fermate 1–100, and Dithane D-14 1 qt.–100. The plots were divided so that some trees received a special bloom application while others did not.

Rust diseases were not difficult to control in 1945. Temperatures during the rain periods when the trees were in bloom and the fruit and leaves were most susceptible were too low for much rust infection

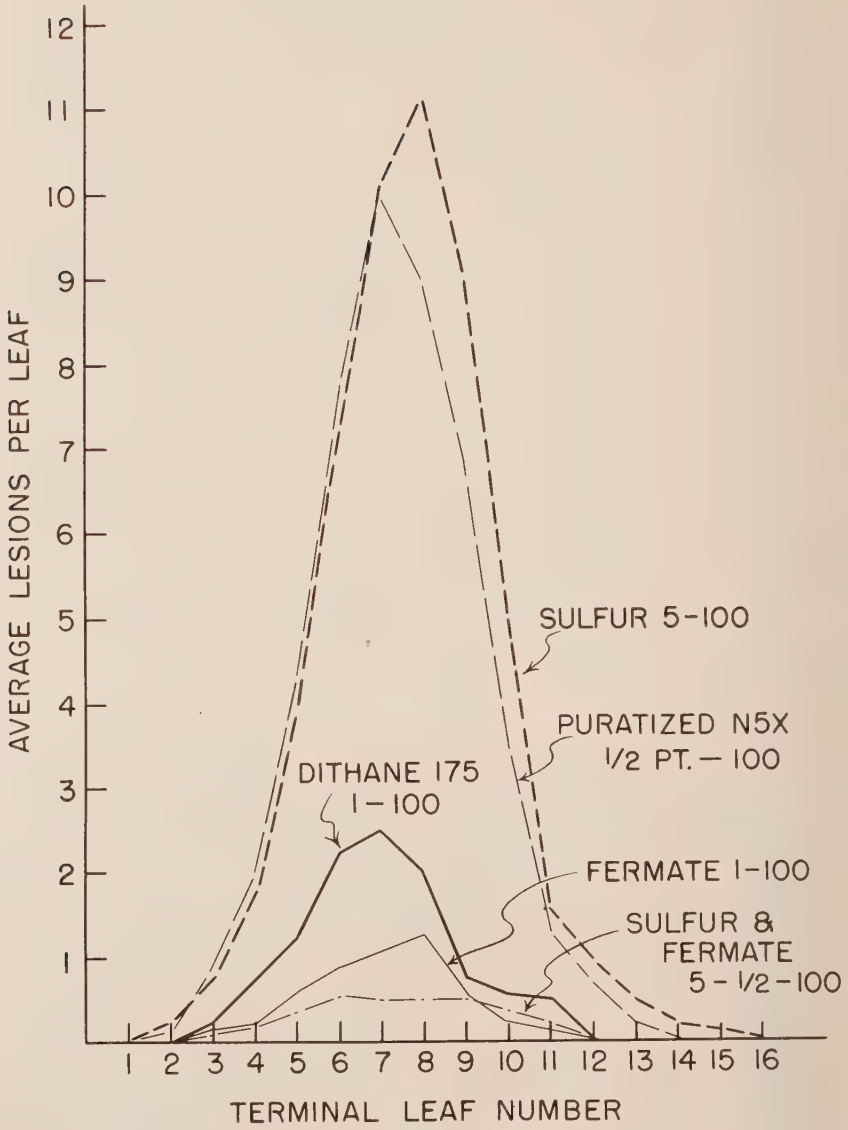

FIG. 10. — *Average number of rust lesions on terminal leaves of Winter Banana trees in spray plots, 1944. Both Micronized sulfur and Puratized N5X failed to give adequate protection from rust. Dithane He 175 afforded better control than sulfur but did not equal Fermate alone or with sulfur.*

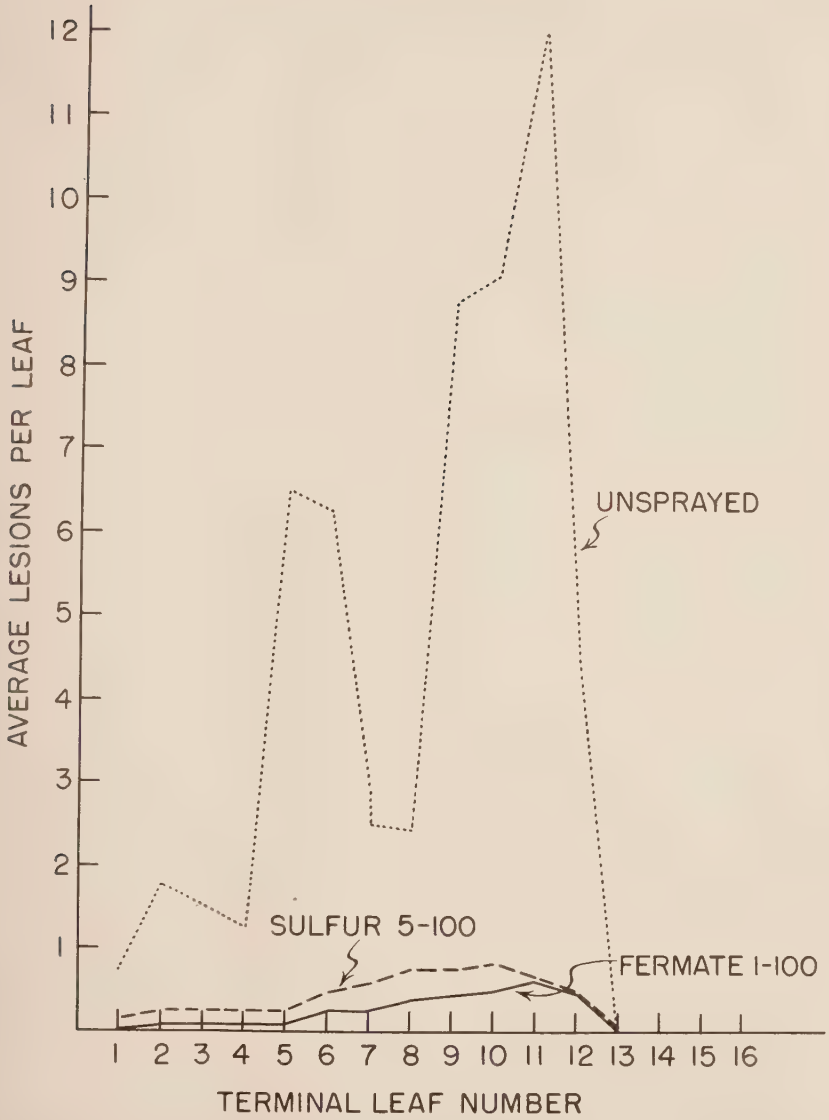

FIG. 11.—*Average number of rust lesions on terminal leaves of Rome Beauty trees in spray plots, 1945. Unsprayed trees showed heavy infection on the 5th and 6th and on the 9th to 11th terminal leaves. With frequent applications, both Micronized sulfur and Fermate provided good leaf protection.*

to occur. It was not until 8 days after petal fall that an infection period occurred which resulted in considerable rust infection on the 10th to 12th terminal leaves. Practically no rust infection occurred after this date.

Micronized sulfur applied April 10, 20, and 30 and May 14 resulted in 97 per cent rust-free fruit and 94 per cent control of leaf infection (Fig. 11). The omission of the bloom application reduced the control on leaves to 90 per cent but showed little effect on fruit infection. Fermate 1–100 in the full schedule resulted in 100 per cent clean fruit and 98 per cent control of leaf lesions. The omission of the bloom application resulted in 95 per cent control of leaf lesions. About one-third of the fruit infections on the sulfur-sprayed trees were caused by quince rust. There was no quince rust in the Fermate plots. Sulfur-Fermate treatments 3–¼–100 and 3–½–100 resulted in leaf rust control intermediate between that of sulfur and Fermate used alone. Dithane D-14 1 qt.–100 gave adequate control of rust but only 75 per cent control of scab. Rust counts on the fruit of unsprayed trees were not obtained because heavy scab infection caused the fruit to drop early.

The trees sprayed with sulfur in the full spray schedule averaged 84 per cent of the fruit infected by Brooks' fruit spot whereas all the Fermate treatments gave complete control of this disease.

1946 Season

The 1946 season advanced at near the normal rate, being about 2 weeks behind the early season of 1945. The bloom period was prolonged by cool weather and lasted from April 27 to May 17. Although the total amount of rainfall for April and May was about normal, there were seven periods when the trees were wet 24 to 40 hours. Such conditions favored both scab and rust infection of the leaves. Light fruit infection by apple and quince rust was perhaps due to low temperatures and to the delay of quince rust spore discharge until after bloom. Leaf lesions were not evident in any great number until June 17, indicating that most of the infection occurred after bloom.

The 1946 tests were made on Rome Beauty trees in the Giles Randall orchard at New Paltz. The trees were of medium size and vigor and cedar trees were abundant in fields less than ¼ mile distant. The test fungicides included Micronized sulfur 5–100, sulfur-Fermate 3–½–100, sulfur-Dithane Z-78 3–1–100, sulfur-Dithane D-14 3–1 qt.–100, and Fermate 1–100.

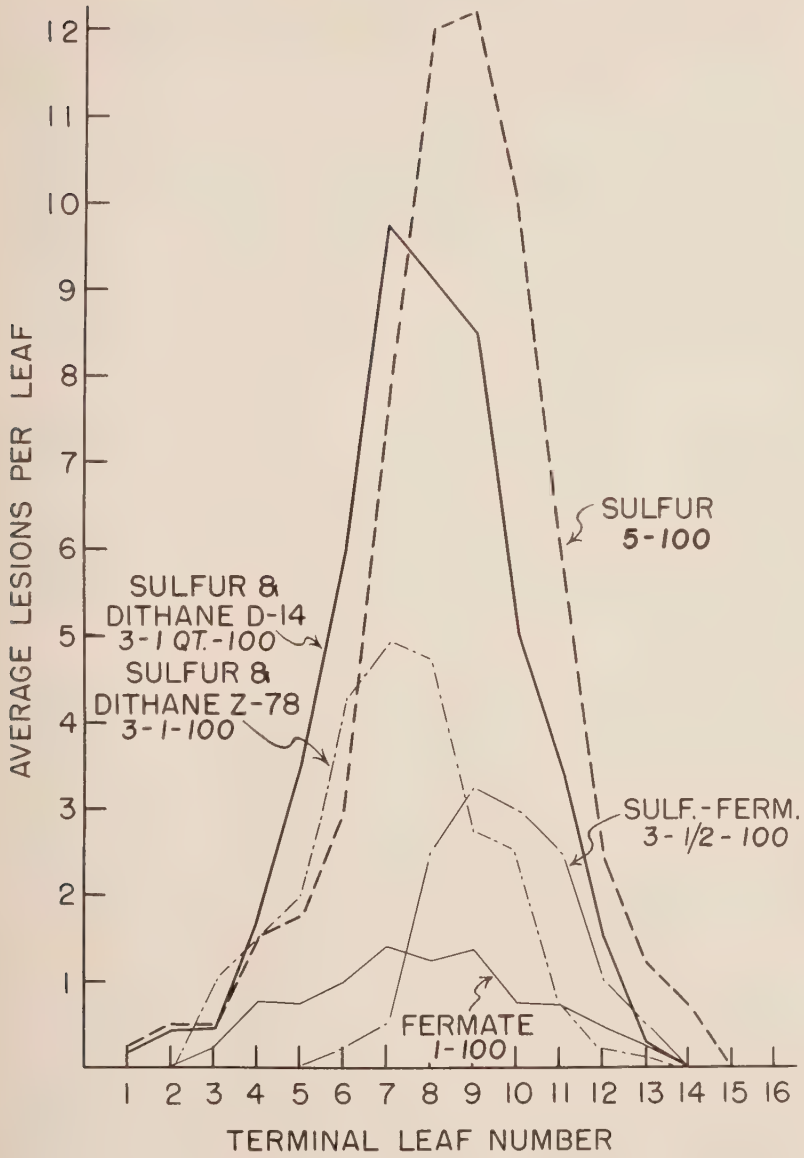

FIG. 12. — *Average number of rust lesions on terminal leaves of Rome Beauty trees in spray plots, 1946. Trees sprayed with Micronized sulfur 5–100 averaged over 12 lesions on the 8th and 9th leaves. The addition of Dithane D-14 1 qt.–100 or Z–78 1–100 to sulfur sprays did not improve rust control as much as the addition of Fermate ½–100. Fermate alone at 1–100 held rust lesions to an average of 1½ per leaf.*

The fungicides were applied as follows: Pink, April 25; bloom, May 9; petal fall, May 17; 10-day, May 28; and a special application on June 6.

Trees that received no fungicide application at the pink, bloom, petal fall, or 10-day periods showed a maximum of 28 rust lesions per leaf on the 8th terminal leaf. Micronized sulfur gave 55 per cent control with 13 lesions per leaf and sulfur-Dithame D-14 gave 65 per cent control with 10 lesions per leaf. Sulfur-Dithane Z-78, sulfur-Fermate, and Fermate alone showed 83, 89, and 95 per cent control, respectively (Fig. 12).

No quince rust infection developed on the fruit and fruit infection from apple rust was light.

Because of abundant rainfall considerable scab developed on the terminal leaves of the unsprayed trees. The scab lesions were counted at the same time the rust counts were made. The unsprayed trees averaged 46 scab lesions per terminal. The combination of sulfur and Fermate gave the best scab control with less than 0.7 lesion per terminal. The other treatments in the order of their effectiveness for scab control were sulfur, sulfur-Dithane D-14, Fermate, and sulfur-Dithane Z-78.

1948 Season

A block of Delicious and Cortland trees in the W. A. McKiernan orchard at Rock City was used for quince rust control experiments in 1948. The treatments were applied as for apple scab control, starting with the delayed dormant spray April 22. This was followed by the pink on May 3, bloom on May 11, petal fall on May 20, and the 10-day on May 28. Fermate was used in all cover sprays on all but the sulfur plots. The test treatments were flotation sulfur paste 10–100, Puratized Agricultural Spray 1 pt.–100, Tag ½ pt.–100, and Phygon-Fermate ¼–¾–100.

Five rainy days occurred during the bloom period with temperatures high enough for quince rust infection May 12, 17, and 18.

Quince rust lesions were evident in early June. By June 18 many apples were dropping because of quince rust infection so counts were made to determine the effects of the fungicide treatments on early drop due to quince rust. Dropped fruit from sulfur-sprayed Cortland trees averaged 26 per cent quince rust. Drops from trees sprayed with Puratized Agricultural Spray and Tag averaged 20 and 7 per cent infection, respectively, and no rust-infected fruits were found under trees sprayed with Phygon-Fermate.

Harvest counts in the Delicious plots showed perfect quince rust control with Phygon-Fermate compared with 91, 89, and 78 per cent control with sulfur, Tag, and Puratized Agricultural Spray, respectively (Table 2).

Cortland fruit counts showed 99 per cent control of quince rust by Phygon-Fermate, and 94, 95, and 97 per cent control where sulfur, Puratized Agricultural Spray, and Tag were used, respectively.

Besides giving the best control of quince rust, the Phygon-Fermate program also controlled scab as well as any other treatment with 100 per cent control on Delicious and 96 per cent control on Cortland (Table 2).

1949 Season

The Cortland trees at Rock City were used in 1949 for a quince rust test as in 1948. The materials tested included Micronized sulfur 6–100, Tag ½ pt.–100, Phygon ½–100, Crag 341C 2 qts.–100, Crag 341C-Fermate 1 qt.–¾–100, and Fermate 1½–100. The test fungicide treatments were started at the delayed dormant stage for scab control on April 13 and continued in the pre-pink, pink, and petal fall applications

TABLE 2. — *Effectiveness of Fungicides for Control of Quince Rust and Scab on Apples at Rock City, N. Y., 1948 and 1949.*

TREATMENT*	PERCENTAGE CONTROL	
	Quince rust	Scab
1948, Delicious		
Flotation sulfur paste, 10–100	91	84
Puratized Agricultural Spray, 1 pt.–100	78	89
Tag Fungicide 331, ½ pt.–100	89	100
Phygon + Fermate, ¼–¾–100	100	100
1948, Cortland		
Flotation sulfur paste, 10–100	94	86
Puratized Agricultural Spray, 1 pt.–100	95	91
Tag Fungicide 331, ½ pt.–100	97	96
Phygon + Fermate ¼–¾–100	99	96
1949, Cortland		
Micronized Sulfur, 6–100	96	95
Tag Fungicide 331, ½ pt.–100	96	96
Phygon, ½–100	97	97
Crag 341C, 2 qts.–100	96	99
Crag 341C + Fermate, 1 qt.–¾–100	100	96
Fermate, 1½–100	99	95

*These treatments were started with the delayed dormant application and continued to the first cover when Fermate was substituted for the mercury and Phygon treatmens. Lime 1–100 was used with Crag 341C before bloom and increased to 3–100 after bloom, but no lime was used in the Crag 341C-Fermate combination.

on April 20, 27, and May 9, respectively. Five cover applications were made for continued scab protection with Fermate substituted for Tag and Phygon.

Quince rust infection was much lighter in 1949 than in 1948 in spite of the omission of a bloom spray and the occurrence of three rains during bloom. Dry weather during the latter part of April apparently held back the development of quince rust galls on the cedar trees so only a few spores were discharged during the bloom period when the apple fruit was most susceptible.

Micronized sulfur 6–100 averaged 95 per cent control of quince rust (Table 2). The Crag 341C-Fermate combination 1 qt.–¾–100 gave perfect control. Tag, Phygon, and Crag 341C when used alone gave slightly better control of quince rust than sulfur. Fermate alone was much better than sulfur for rust control and equal to sulfur in the control of fruit scab.

Apple rust lesions were quite abundant on leaves of Golden Delicious trees. These trees received the regular apple scab sprays without a special bloom application. Sulfur-sprayed trees averaged 23 lesions per leaf compared with 20, 19, and 4 lesions, respectively, for Crag 341C, Phygon, and Fermate.

In the Zimmer orchard at Poughkeepsie, rust developed on R. I. Greening and Northern Spy trees that had been sprayed for scab with various fungicides. While the incidence of infection was low on these partially resistant varieties, the results indicate the relative effectiveness of the fungicides in controlling this disease. Fermate alone or in combination with Crag 341-C gave the best control of rust. Crag alone did very well and was followed in order by Puratized Apple Spray, Tag, Phygon, and Cr-305. On Rome Beauty Cr-305 averaged only 75 per cent control of apple rust on the fruit compared with 97 per cent control with Fermate.

1952 Season

Orthocide 406 and combinations of Orthocide 406 with ferbam were tested on Delicious, Jonathan, and Cortland varieties for control of quince rust. Orthocide alone at 2–100 did not give as complete protection as ferbam alone at 1½–100, but fruit infection was held to about 1 per cent compared with 14 per cent infection on unsprayed trees. The Orthocide-ferbam combination at 1–¾–100 gave almost perfect control of both rust and scab.

Experiments with Dust Materials[7]

Methods

Limited dust experiments were conducted during 1942, 1943, and 1944 in a block of Rome Beauty and Golden Delicious trees on the farm of Fred DuBois near New Paltz. The dusts were applied with a flexible outlet Niagara Duster. The dust treatments were applied more frequently than the spray treatments, and a fresh dust coverage before each rain period was attempted. The applications were usually made in early morning or at night when the trees were wet with dew and the air was calm. The dust was applied to both sides of each row of trees.

Records on the amount of fruit and leaf infection were taken in the same manner as described for the spray treatments. The amount of apple and quince rust on the fruit was recorded separately, but no distinction was made between hawthorn and apple rust lesions on the leaves.

All of the dusts applied following bloom contained 15 or 20 per cent arsenate of lead for insect control.

Results

1942 Season

In 1942 a straight sulfur dust was compared with a Fermate-sulfur dust containing 3.75 per cent Fermate. As a control, another plot was sprayed with Micronized sulfur 5–100. There were nine applications of dust compared with six spray applications. Little rust developed this season, but both dust treatments showed improved control of leaf infection compared with the sulfur spray treatment, probably due to the more frequent dust applications.

1943 Season

The dusts were similar to those used in 1942. The sulfur dust program resulted in 91 per cent control of fruit infection, while the Fermate-sulfur dust showed 95 per cent control. An unsprayed tree showed 10 per cent of the fruit infected by cedar-apple rust and 7 per cent infected by quince rust. The foliage averaged over five rust lesions per leaf on the 5th and 6th terminal leaves compared with one lesion per leaf in the sulfur dust plot and only a trace of rust in the Fermate-sulfur plot (Fig. 13).

[7]The dust materials were supplied by E. I. duPont de Nemours and Company, Inc., Wilmington, Delaware. The particle size of the sulfur dust was approximately 6.6 microns and the same sulfur was used as a carrier for Fermate except for one plot in 1944 where Fermate was used with talc as the carrier.

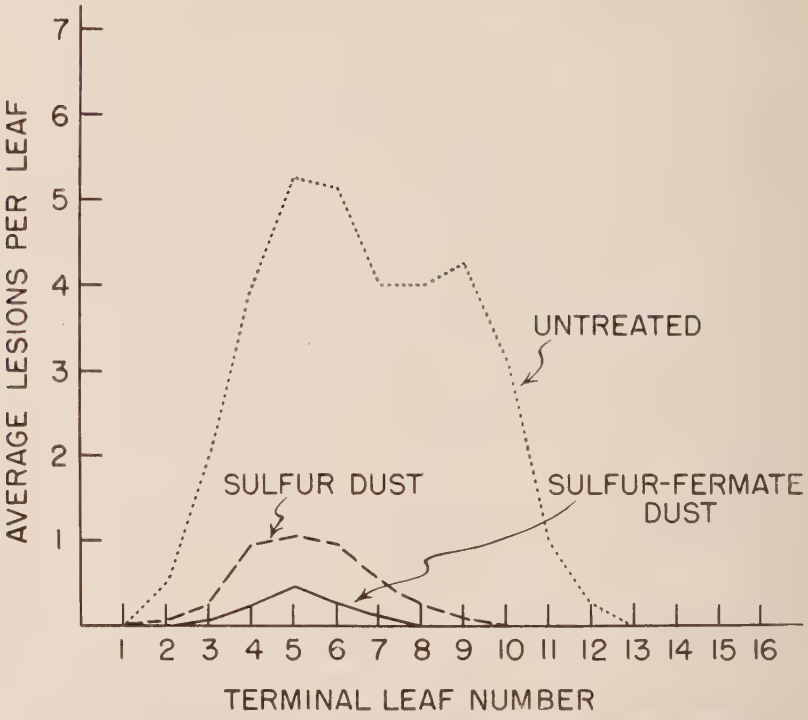

FIG. 13.—*Average number of rust lesions on terminal leaves of Rome Beauty trees in dust plots, 1943. Untreated trees averaged over 5 lesions on the 5th and 6th leaves compared with 1 lesion per leaf on the sulfur dust plot and only a trace when the sulfur dust contained 3¾ per cent Fermate.*

1944 Season

A 4 per cent Fermate-sulfur dust was compared with a 10 per cent Fermate-talc dust and a straight sulfur dust. Fruit infection was light this season even on the unsprayed tree, but considerable leaf infection developed. The foliage averaged 220 lesions per terminal. Trees dusted with sulfur, Fermate-sulfur, and Fermate-talc showed reductions in leaf rust infections of 82, 93, and 96 per cent, respectively.

While these dust experiments were not extensive, they confirm observations made in commercial orchards that a sulfur dust containing 3 to 4 per cent ferbam can give satisfactory control of rusts on both fruit and leaves if applications are timely.

Discussion and Conclusions

Field trials from 1941 to 1949 have shown that cedar-apple, hawthorn, and quince rusts can be easily controlled under New York conditions by three or four applications of ferbam fungicides, beginning with the pink and ending with the second or third spray after bloom. In years when rust infection was not severe, such as 1942, 1945, 1947, and 1950, sulfur alone gave good control if the sprays were carefully timed. In years more favorable for rust infection, such as 1941, 1943, 1946, and 1948, sulfur alone failed to control either fruit or leaf infection as well as ferbam.

As pointed out by Hamilton,[8] "Perfect control, however, was obtained (with sulfur) only when the spray applications immediately preceded the wetting periods that produced the infection. When 2 to 5 days elapsed between the dates of application of effective materials and infection periods, an average of about two young leaves per terminal was somewhat infected."

Such close timing with ferbam fungicides is not necessary since the active part of this material is translocated both externally and internally to such an extent that new growth is protected.

Hamilton, Palmiter, and Weaver[9] point out, "Greenhouse studies on potted apple trees indicate that the toxic element in Fermate is taken into the plant in sufficient amounts to give a degree of protection through systemic action, particularly against the cedar-rust fungus." This is especially true when 1 or 1½ pounds are used per 100 gallons of spray. When used at these higher rates the bloom application for rust control can usually be omitted, but if only ½ pound of Fermate is used a bloom spray will be required if rain occurs during bloom.

Fermate used alone at 1 or 1½–100 or used at ½ pound with 3 pounds of sulfur in the regular sprays recommended for apple scab control has never failed in experimental field tests to give satisfactory control of both cedar-apple and quince rust.

Since apple scab, *Venturia inaequalis* (Cke.) Wint., is the major fungus disease of apples in New York, it is important that any fungicide used for the control of the rust diseases control scab as well. Abundant field data[10] have indicated that Fermate 1½–100 will control scab as

[8]Hamilton, J. M. *Loc. cit.*

[9]Hamilton, J. M., Palmiter, D. H., and Weaver, L. O. Evaluation of Fermate for the control of apple scab and cedar-apple rust fungi. *Phytopath., 33: 5. 1943.*

[10]Hamilton, J. M., and Palmiter, D. H. Orchard tests for apple scab control in New York State: I. Sulfur fungicides. *New York State Agr. Exp. Sta. Bul. No. 747: 1–63. 1951.*

well as the best dry wettable sulfur fungicides. Fortunately, many of the apple varieties that are most susceptible to cedar-apple rust, such as Wealthy, Jonathan, Rome Beauty, and Golden Delicious, are not as susceptible to scab as McIntosh. Thus it is possible to control both scab and rust on these varieties with Fermate 1–100.

A combination of sulfur and ferbam has also been used with good results for the control of both diseases. A sulfur-Fermate mixture 3–½–100 has given good control of cedar-apple and quince rust and usually resulted in better scab control than was obtained with either sulfur or ferbam used alone at full strength. Concentrations of Fermate as low as ¼ pound have been used with sulfur with satisfactory results in experimental tests, but the ½ pound rate is considered more practical since it affords longer protection against rust infection and gives better scab control. The use of sulfur-Fermate 4–¾–100 has given improved scab and quince rust control on McIntosh.

Most of the carbamate group of fungicides show marked toxicity towards the rust fungi. Ferbam products, however, have proved best to date for the control of apple rust diseases under New York conditions. They cause less injury and are less expensive or give better scab protection than the ziram, zineb, or nabam fungicides tested.

Under many commercial orchard conditions where rust is not a serious problem, several fungicides other than ferbam have given commercial control of rust. These include sulfur, Phygon, Orthocide 406, and Crag 341C. Additional rust protection may be obtained by adding ferbam when these materials are being used during the critical rust infection period (pink, bloom, and petal fall applications).

In general, the phenyl mercury fungicides are not good rust fungicides.

Combinations of ferbam with such materials as Tag, Puratized Agricultural Spray, and Dynacide have been used experimentally with good results.